Response to Referees

We have addressed all the referees' comments.

Our rebuttal for all referees is presented in separate documents as the format requests. A modified manuscript that addressed the referees' major suggestions was prepared. Finally, we would like to acknowledge all the referees and editors for spending their time and effort sharing their view and providing constructive comments.

NOTE:

- The blue font indicates the response given by us authors.
- ***Fig. x*** refers to figure number in the main manuscript
- ***Figure y*** refers to figure in this response letter but not in the main manuscript. Parts of figures included in the manuscript are indicated in parenthesis under each figure's caption.

Interactive comment on "Evaluation of surface properties and atmospheric disturbances caused by post-dam alterations of land-use/land-cover"
By A. T. Woldemichael et al. (HESS-2014-125)

Anonymous Referee #2

Received and published: 26 June 2014

Summary:
The authors employed the use of a regional climate model to identify the effects of dam and irrigation related LULC change. One control scenario and two theoretical scenarios were run. Precipitation, surface temperature, turbulent heat fluxes, wind, atmospheric water vapor, and soil moisture fields were analyzed, as well as planetary boundary layer development, in an attempt to identify the modification of LULC dependent land-atmosphere interactions. This study provides a useful follow up to Woldemichael et al. (2012, 2013) papers, which analyzed modification of extreme precipitation during the same study period. The paper fits well within the scope of the journal, and a clear objective and precedent is outlined.

MAJOR COMMENTS:

COMMENT 1: It is unclear if all scenario simulations are initialized with the same data, and "nudged" using data assimilation towards the same observations? Or was this only used on the control run?

Our Response: *The RAMS simulations for all scenarios were in fact initialized with the same NCEP/NCAR reanalysis datasets. The land-use and land-cover patterns for each scenario, however, were different. The objective was to see the sensitivity of these LULC variations in modulating the different atmospheric parameters that resulted in precipitation modification.*

A continuous (every model time step) four dimensional dynamical data assimilation (4DDA) was activated in RAMS for each scenario as well. In this assimilation technique, forcing functions are added to the governing model equations to gradually 'nudge' the model states towards the observations through Newtonian relaxation technique. Nudging relaxes the model state towards the observed state so that the model forecasts do not drift away in their own state.

COMMENT 2: It is not clear to me after reading this paper, as well as two other publications from the same group discussing these same simulations, whether or not any spin up would be required for these theoretical cases. Fields derived from the NCEP/NCAR Reanalysis are inherently tied to the contemporary LULC scenario. Similarly, it seems that the data assimilation could further exacerbate this problem, as forcing the model to towards observations that are dependent on a different LULC could mask any feedbacks that would otherwise be present. Further evidence and discussion about why these methods were employed is necessary.

Our Response: *We thank the reviewer for the comments. As mentioned in the previous response, the 4DDA was activated to nudge the simulated values to the observed ones and <u>avoid undesirable model noise and drift</u>. The nudging procedure does not necessarily force the model simulations to observations. It maintains model stability by avoiding unnecessary model drift away from the observations within certain degree of freedom so that the LULC feedback will not be diminished in the simulations.*

The spin-up procedure was an ensemble experiment implemented to observe trend of model performance. The ensemble technique involves perturbing the initial conditions of the model atmospheric fields ((NCEP/NCAR in our case) by a certain amount. Accordingly, we have established two experiments: 1) with a 5% increase of the wind speed, temperature, relative humidity and a changed wind directions, and 2) with a 5% decrease of wind speed, temperature, relative humidity. Results of the simulation indicated almost similar patterns with the unperturbed NCEP/NCAR simulations as shown in Figure-1a for ARW and b for ORW. Since the analyses were made at different times, the observed basin average is omitted in the ORW analysis and NARR analysis is included while NCEP/NCAR basin average analysis represents the control for ARW. In summary, we conclude, here, that the results are not sensitive to a slight change in the initial conditions because the system is strongly forced by surface boundary conditions including terrain.

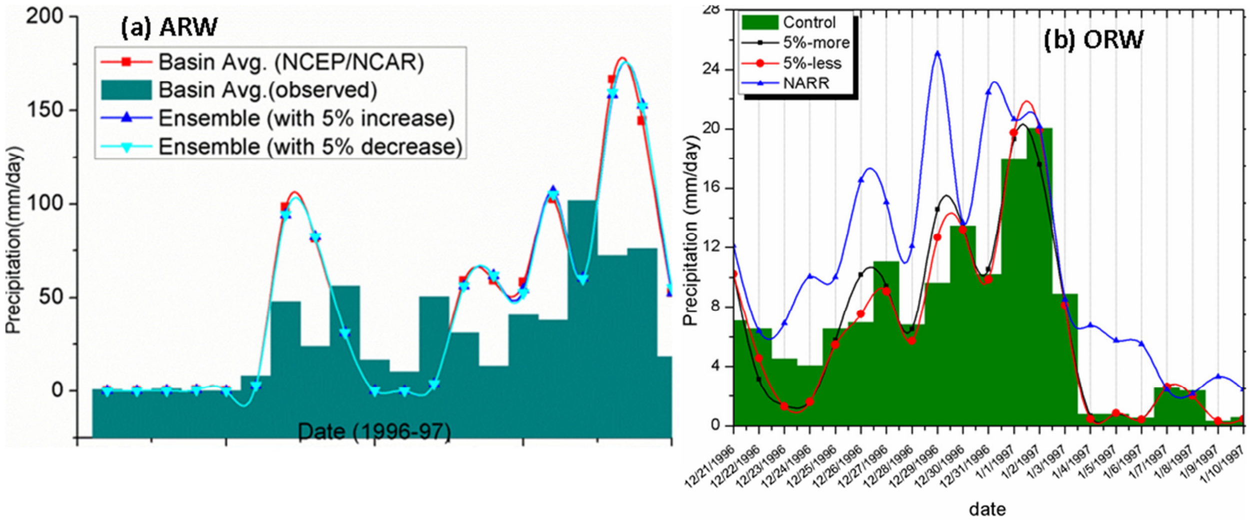

Figure-1*: Basin average precipitation (mm) among the control (NCEP/NCAR), NARR, 5%-more and 5%-less ensemble scenarios.*

1. The authors present an interesting discussion of CAPE development conditioned on the different scenarios, but Fig. 12 and Fig. 13 only show results from the control case, and no direct comparison of CAPE between the simulations is made. The results are presented very well in the figures, but the discussion could be more developed.

Our Response: *We thank the referee for the comment. We have replaced Fig. 12 and 13 with the following figures in the manuscripts and the follow-up discussion is expanded accordingly. The underlined statements are included in the improved manuscript:*

"Finally, to understand the availability of potential energy and convective contribution for precipitation formation, a Convective Available potential Energy (CAPE) analysis, was performed. Fig. 12 indicates the amounts of CAPE in the atmosphere for ARW and ORW respectively during the time of maximum CAPE (Jan 3^{rd} 1997) out of the considered 6-days of analysis. Although the CAPE values were not large enough to warrant a convective initiation in the regions, there was a progressive increase in CAPE value from the pre-dam to the non-irrigation and to the control, mostly in the ARW. In all cases, the observed increase in CAPE originated from the increase in the latent heat flux in much of the northwest in ARW and eastern parts of ORW. There is also the important question as to how LULC affects these synoptically driven winter time systems. Since positive CAPE is recognized as a major factor that is altered by LULC, yet, during most days in the winter in the study regions, there is no CAPE, the general impression is that LULC effects on precipitation cannot work in these situations.

However, during these synoptically driven rain events, CAPE is often quite positive. Severe thunderstorms [with documented strong convective instability] and even tornadoes occur during these events [e.g. Hanstrum et al 2002, Kingsmill et al 2006]. [see also https://ams.confex.com/ams/pdfpapers/115125.pdf]. Our results indicated that during these precipitation events, a significant fraction involves deep cumulus clouds, and thus changes *in CAPE, and other thermodynamic aspects of the atmosphere by LULC result in alterations in precipitation from what otherwise would have occurred.*

In order to see how the CAPE varies among the different scenarios, CAPE differences between control and non-irrigation as well as control and pre-dam are shown in Fig. 13. Fig. 13 represents the six day day-time average differences in CAPE. According to Pielke (2001), a larger fraction of energy partitioned to latent heat flux results in greater CAPE and added moisture to facilitate deep convection provided that suitable conditions exist. Looking at Fig. 13 it is apparent that in both regions a larger CAPE is observed for the control as compared to the non-irrigation and pre-dam. These larger CAPE values are especially prominent at location where irrigation was intensified. In non-irrigated regions, there is larger sensible heat flux that doesn't favor CAPE than the latent heat flux. On the contrary, irrigation will add significant latent heat flux resulting from transpiration of water vapor. For larger irrigated areas, there is a possibility of development of mesoscale circulation. However, as discussed previously in such synoptically driven regions as ARW and ORW, the possibility of CAPE being a factor for generating a storm is minimal.

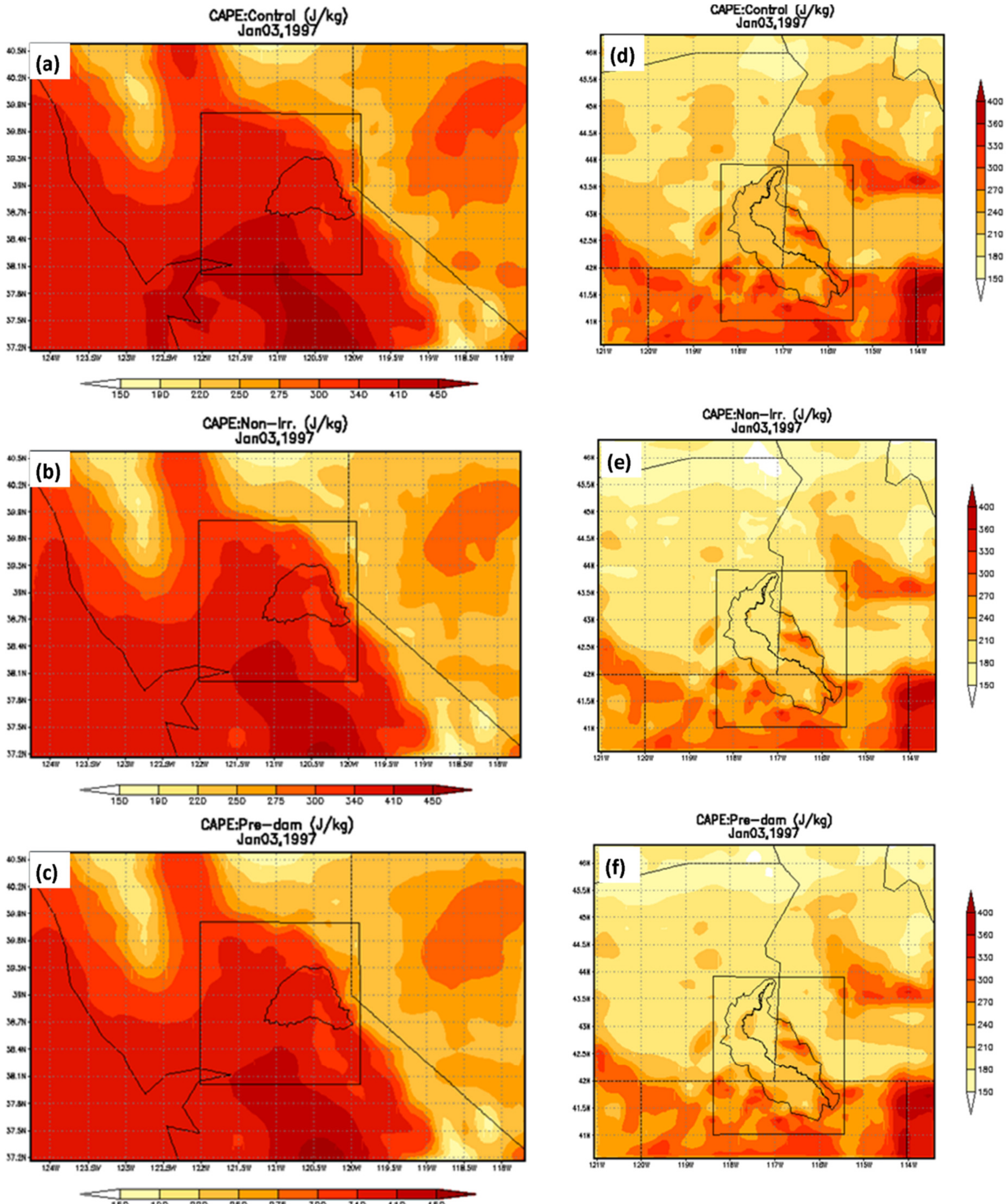

Fig. 12: Daytime average Convective Available Potential Energy (CAPE, J kg^{-1}) for the 3rd of Jan 1997 for ARW control, non-irrigation and pre-dam(a, b &c) and ORW control, non-irrigation and pre-dam (d, e & f).

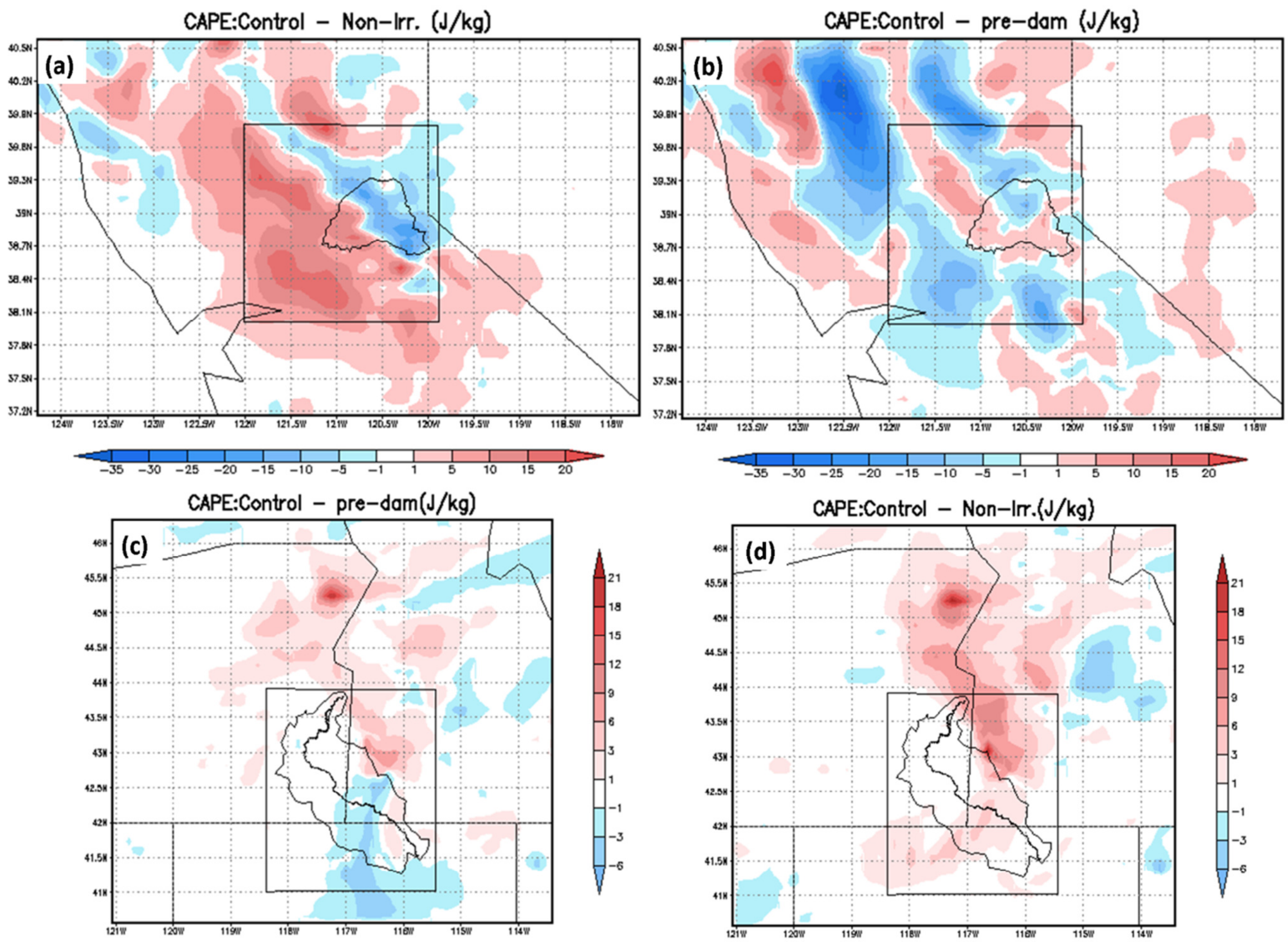

Fig. 13: Differences in Convective Available Potential Energy (CAPE, J kg^{-1})for ARW and ORW control – non-irrigation (a &d)and ARW and ORW control – pre-dam (b &c). note that values are six day daytime averaged for Dec 29th 1996 to Jan 3rd 1997.

COMMENT 3: The discussions of Fig. 5 and 6 are based on the maximum differential of the variables, but the spatial patterns and variability are not thoroughly discussed. In order for the conclusions to be made clearly, a more robust numerical analysis would be helpful.

Our Response: *We thank the referee for the comment. However, the discussions following section 4.1 of the manuscript didn't only focus on the maximum differentials. However, be believed that following Fig. 6 the observed changes in sensible and latent heat fluxes at the ARW location clearly show some patterns clearly showed certain pattern that were not explained in detail. As a result, we have included the following underlined statements in section 4.1 of the modified manuscript:*

"In ARW, the exact location were the previously irrigated land was converted to nearest land-use pattern (i.e. woody savanna) in the control – non-irrigation case, showed a decrease in the sensible heat flux on the order of 15 W/m2 or greater. The decrease in sensible heat flux can be due to the hypothetical replacement of the woody savanna in the non-irrigation scenario with the existing cropland in the control. Crops transpire more due

to their lower stomatal resistance and increased evapotranspiration. This intern cooled the surface as shown in Fig. 5 and hence reducing the outgoing radiation in the form of sensible heat flux."